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(54) **THIN FILM CAPACITOR**

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H01G 4/228	(2006.01)
H01G 4/20	(2006.01)
H01G 4/06	(2006.01)
H01G 4/33	(2006.01)
H01G 4/38	(2006.01)
H01G 4/232	(2006.01)

(52) **U.S. Cl.**

CPC ***H01G 4/306*** (2013.01); *H01G 4/228* (2013.01); ***H01G 4/33*** (2013.01); ***H01G 4/38*** (2013.01); ***H01G 4/232*** (2013.01)

(58) **Field of Classification Search**

CPC H01G 4/228; H01G 4/30; H01G 4/38; H01G 4/33; H01G 4/306

USPC 361/306.1, 311, 312, 313, 301.4

See application file for complete search history.

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(57) **ABSTRACT**

A thin film capacitor includes an under electrode, a plurality of dielectric body layers and a plurality of internal electrode layers that are alternately laminated on the under electrode, the internal electrode layers respectively including protrusion parts that each protrude from the dielectric body layers viewed in the lamination direction, and connection electrodes to which at least a portion of each of the protrusion parts contacts. Assuming that protrusion amounts of the protrusion parts of the internal electrode layers that are connected to the same connection electrode are regarded as L, a protrusion amount L_n of a protrusion part of n^{th} ($n \geq 2$) internal electrode layer from the under electrode side is smaller than another protrusion amount L_{n-1} of another protrusion part of $(n-1)^{th}$ internal electrode layer.

18 Claims, 4 Drawing Sheets

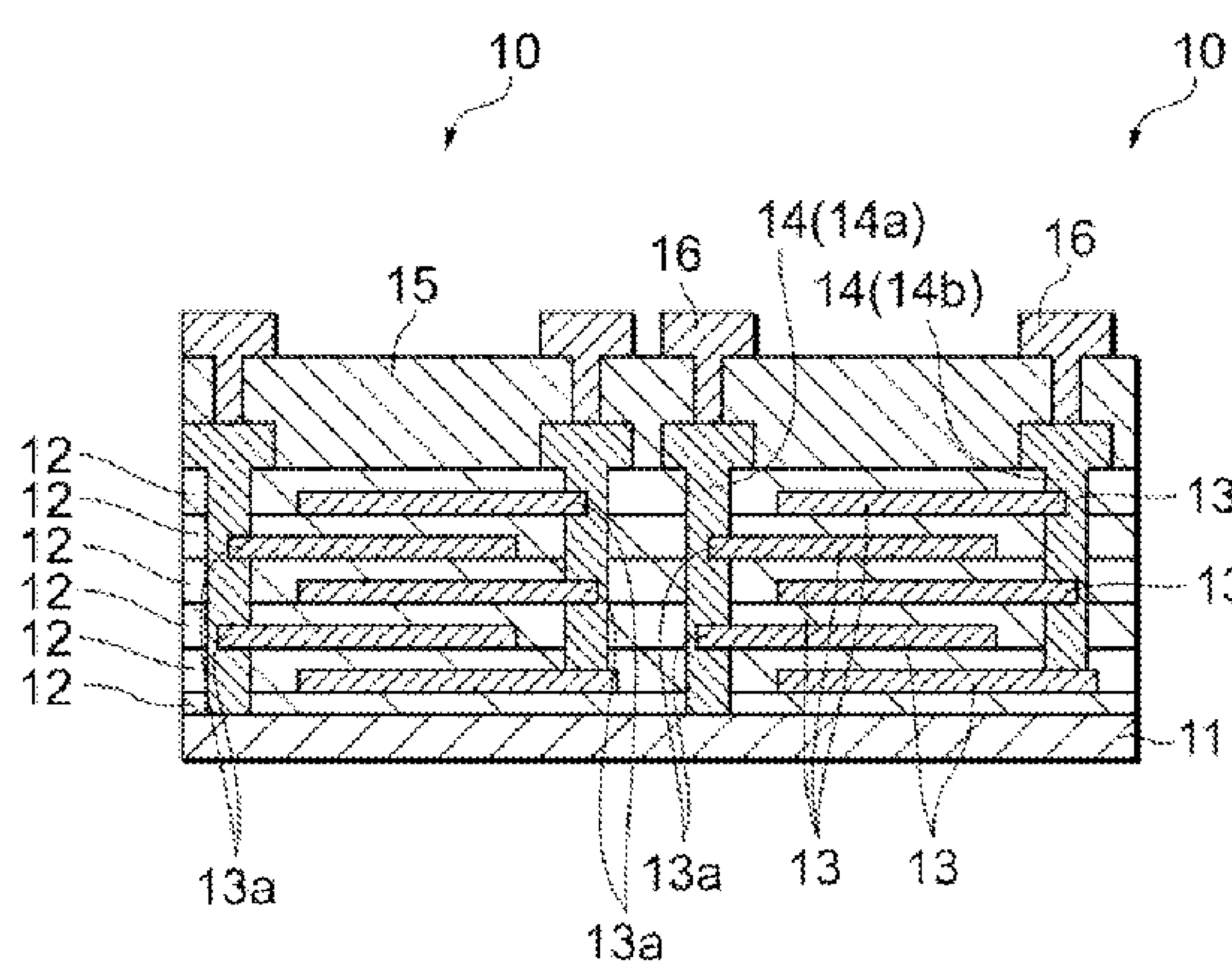

Fig. 1A

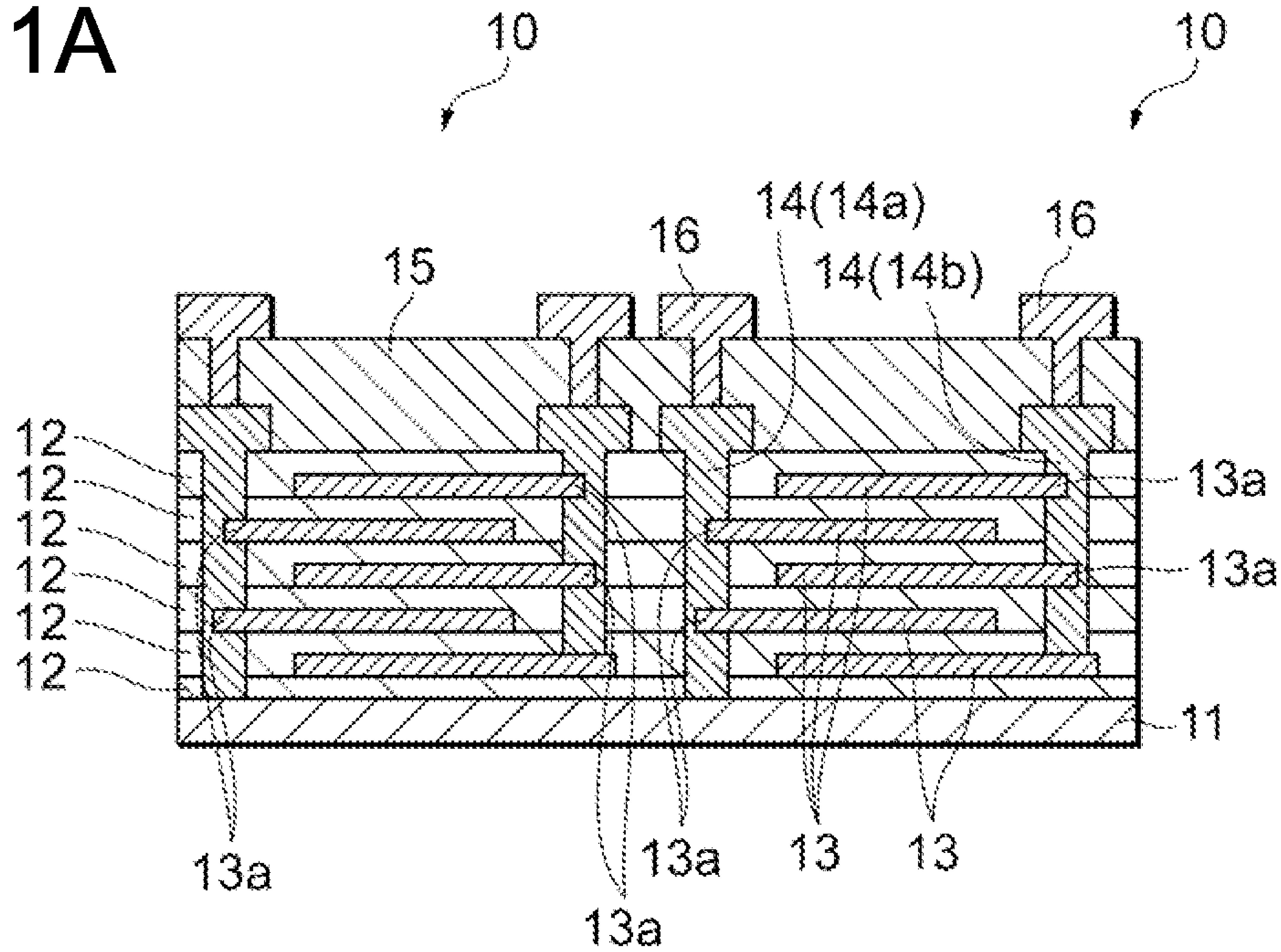
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Fig. 1B

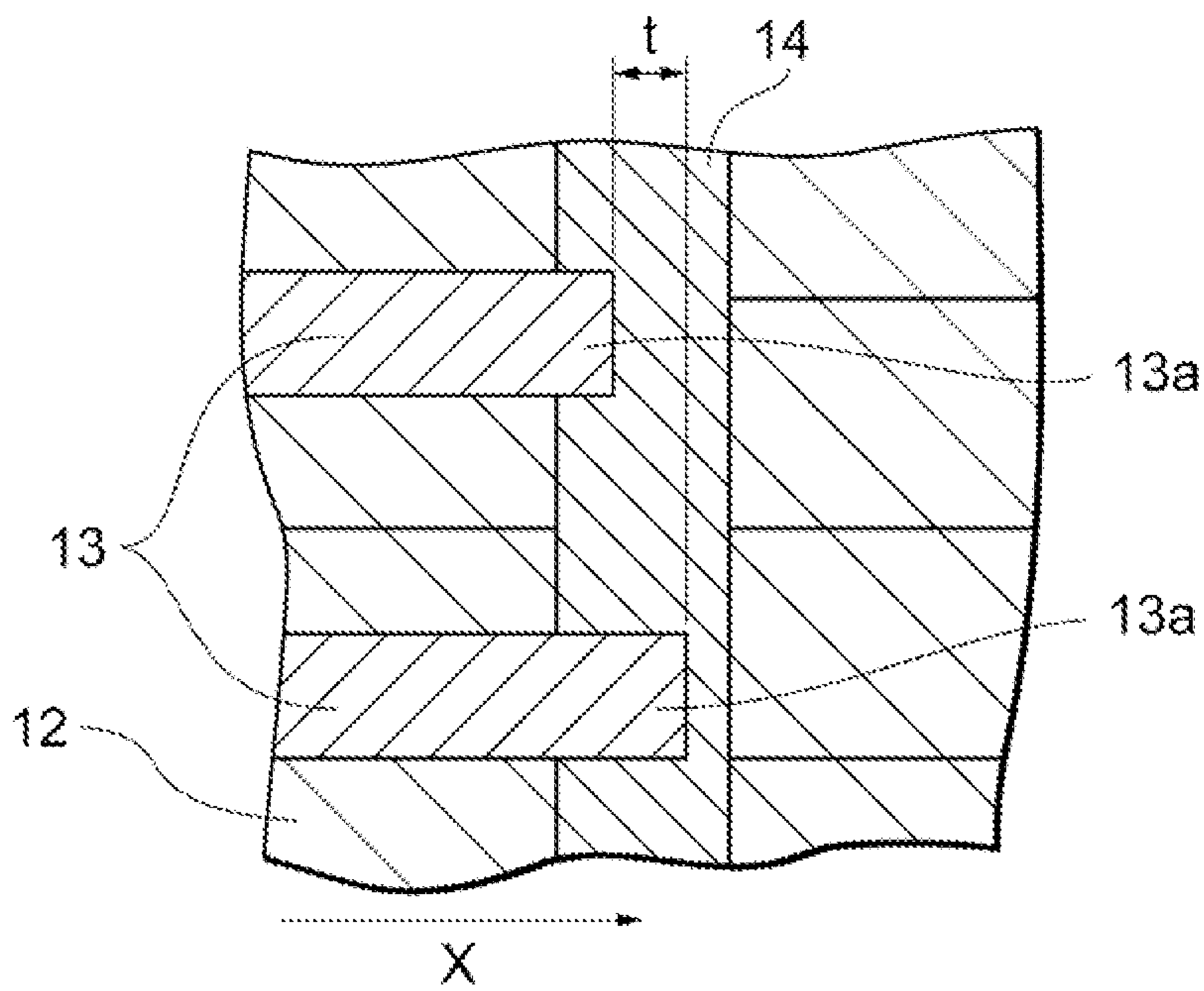
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Fig. 2A

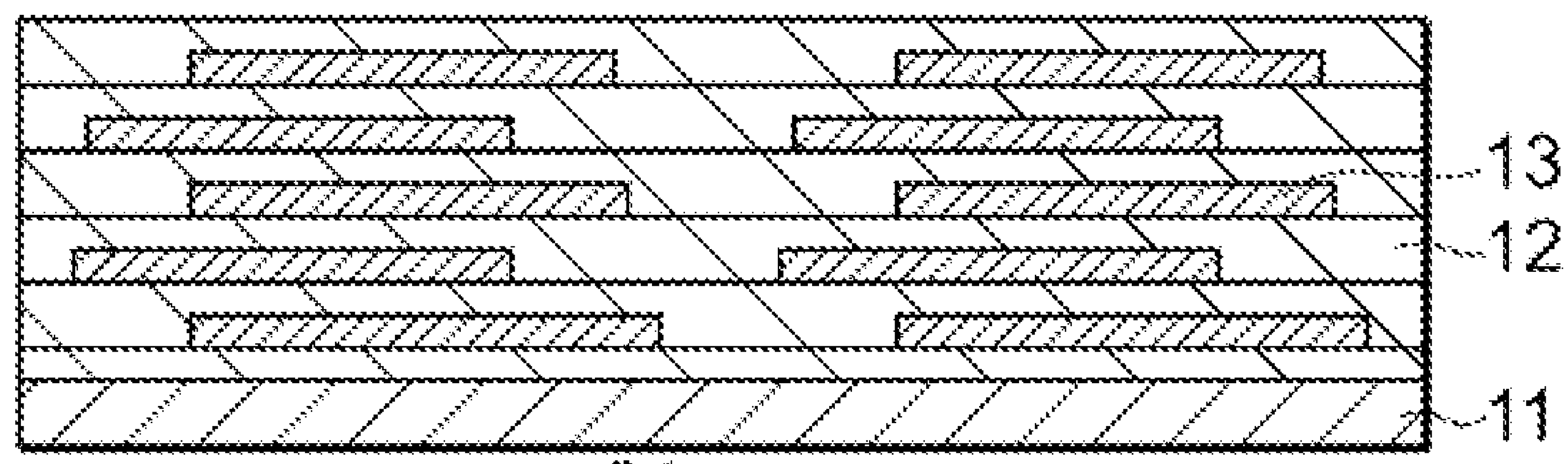


Fig. 2B

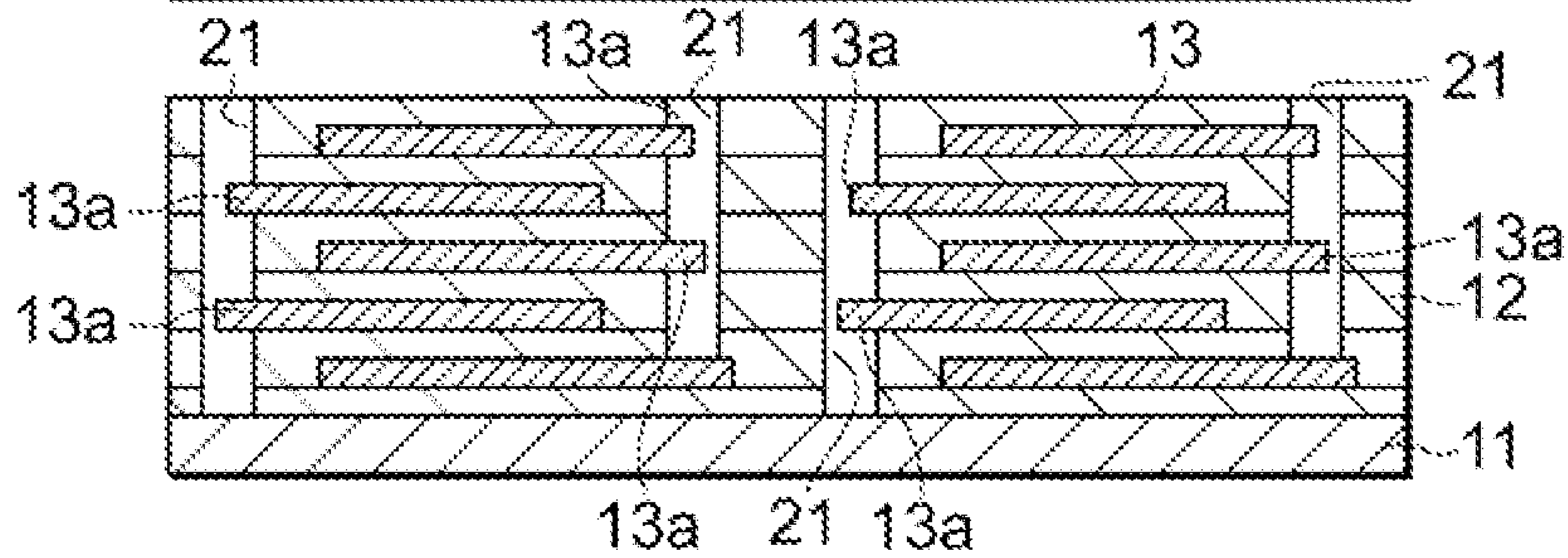


Fig. 2C

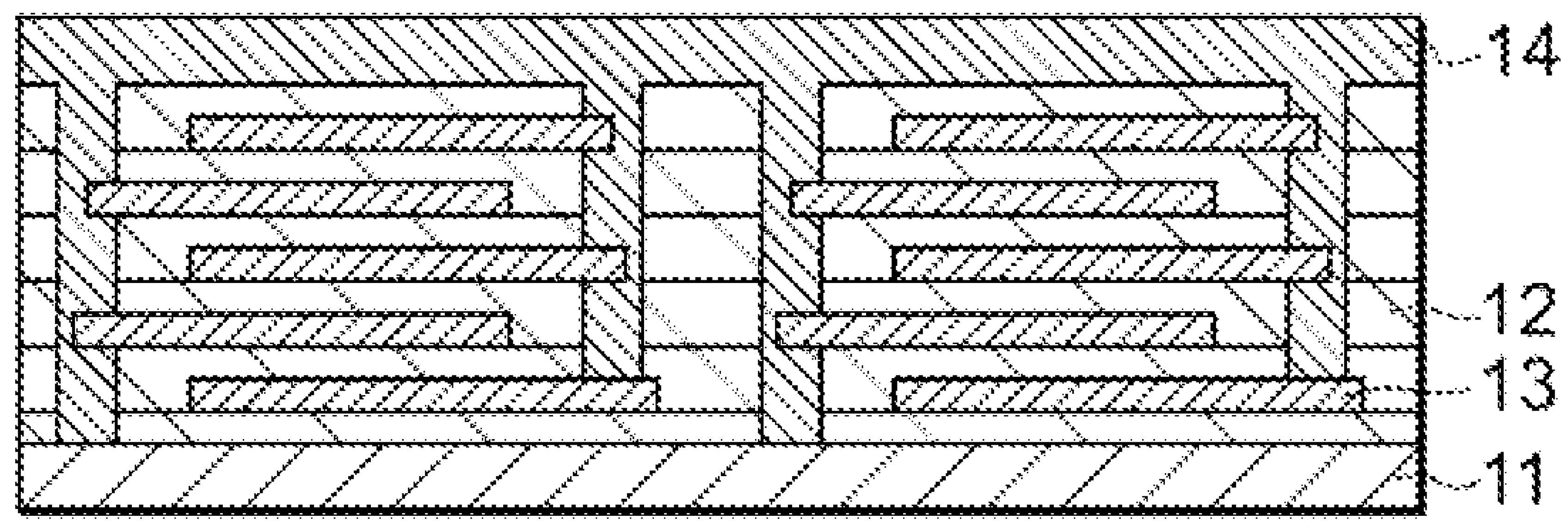


Fig. 2D

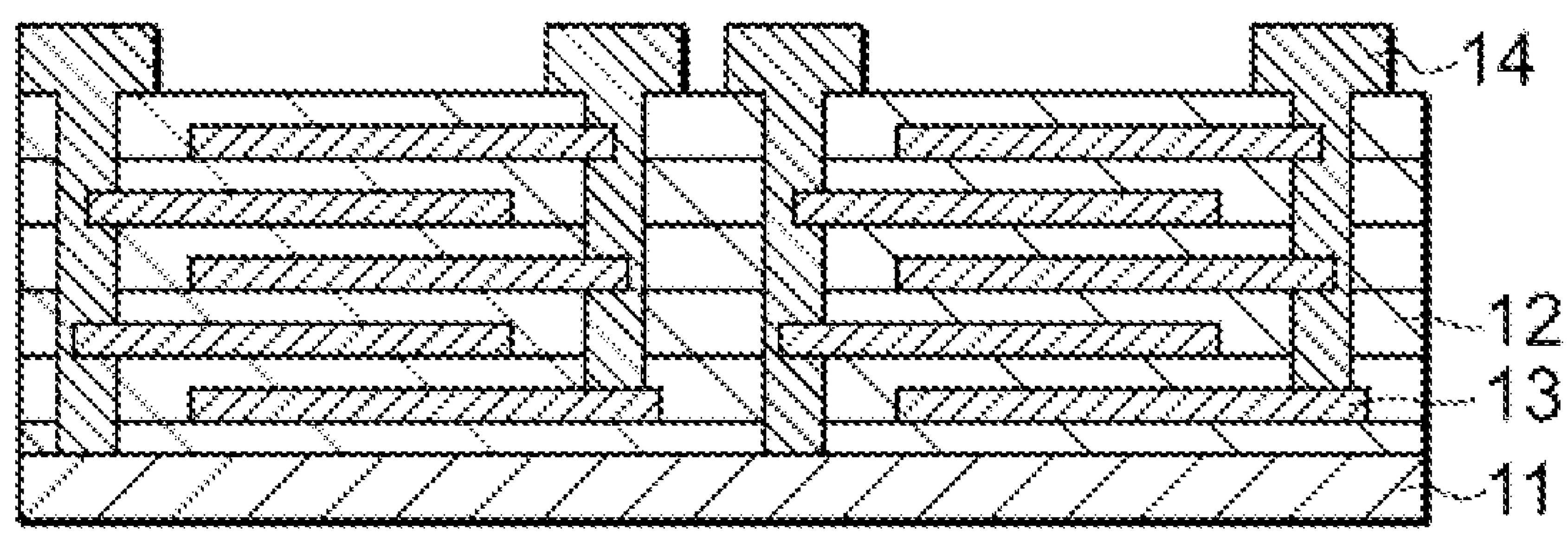


Fig. 2E

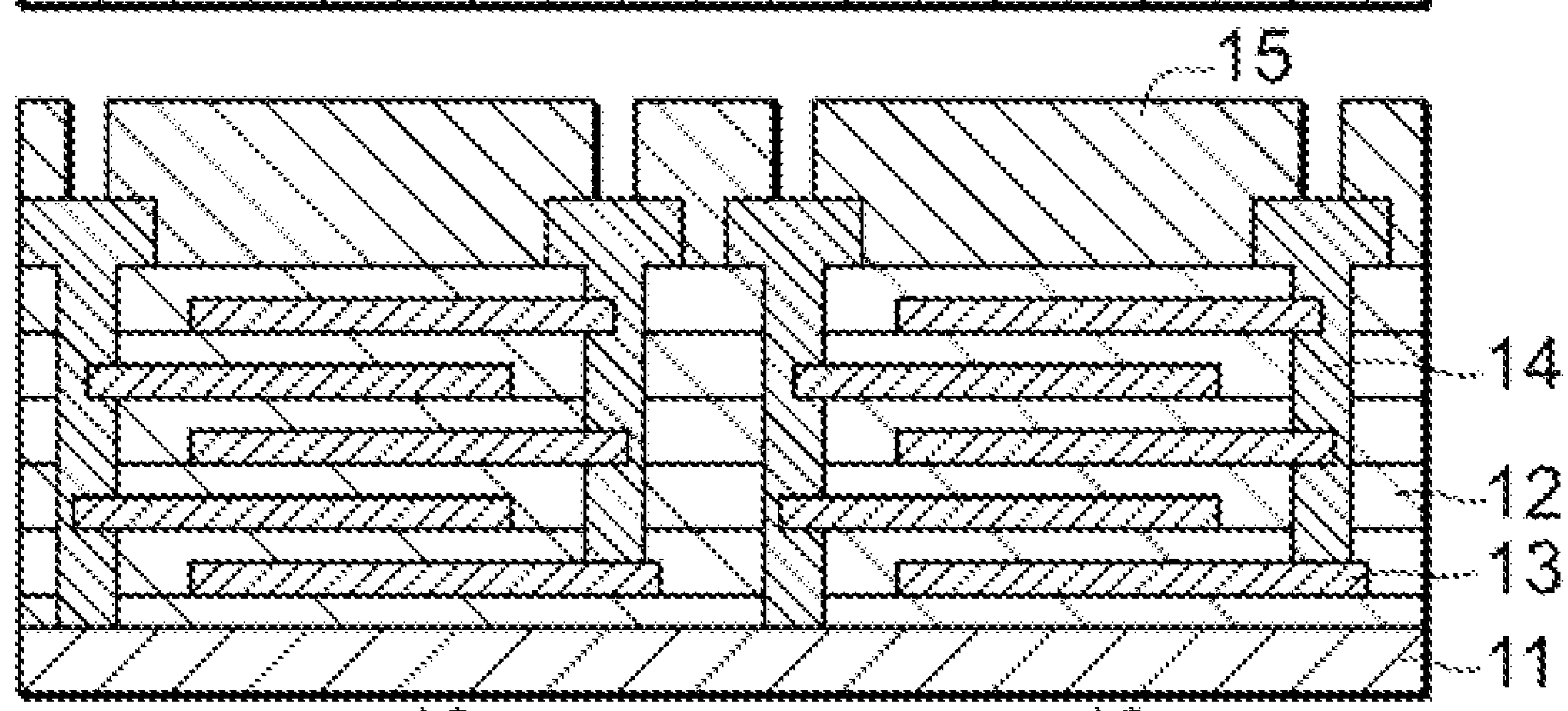


Fig. 2F

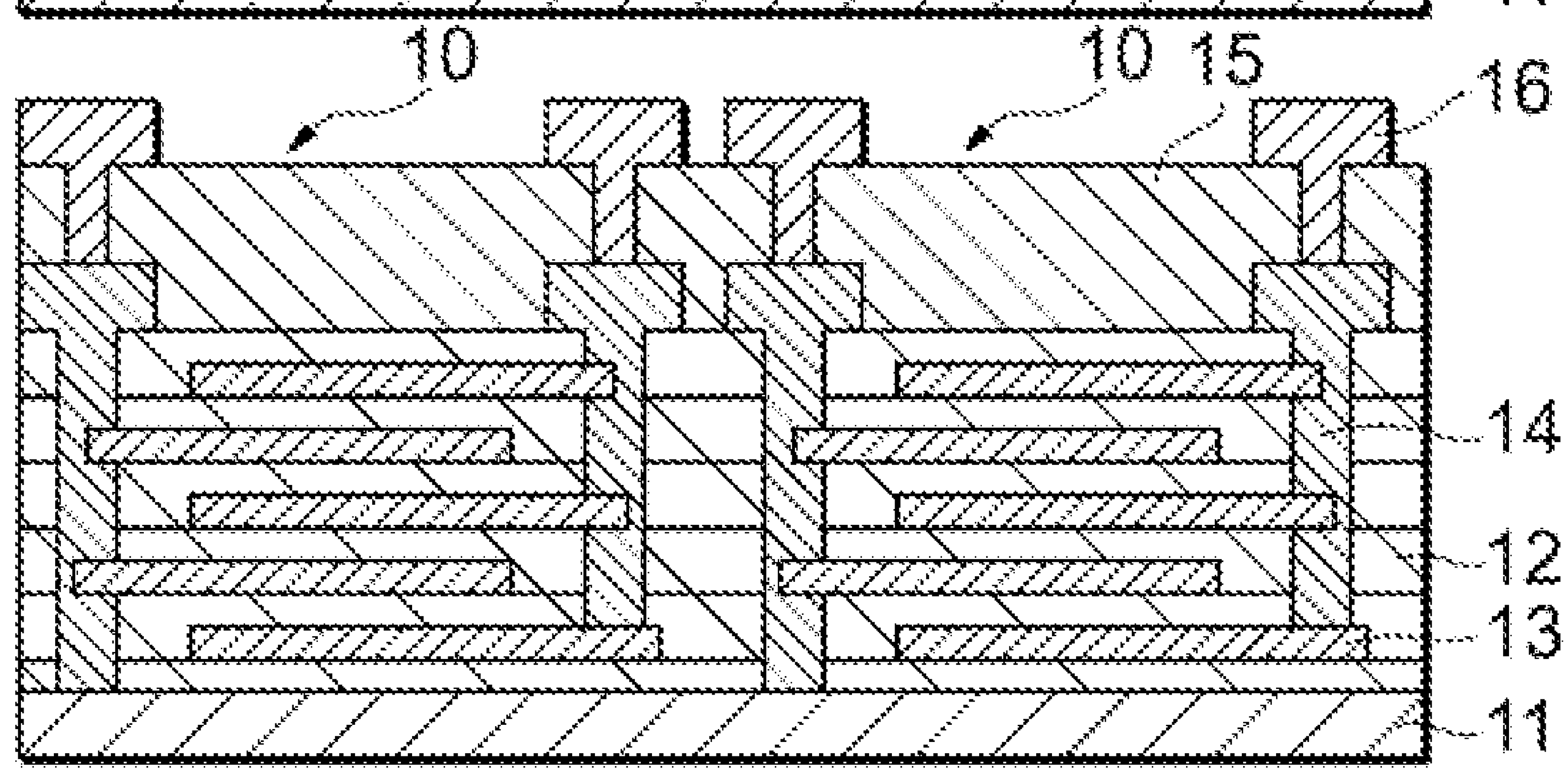


Fig. 3A

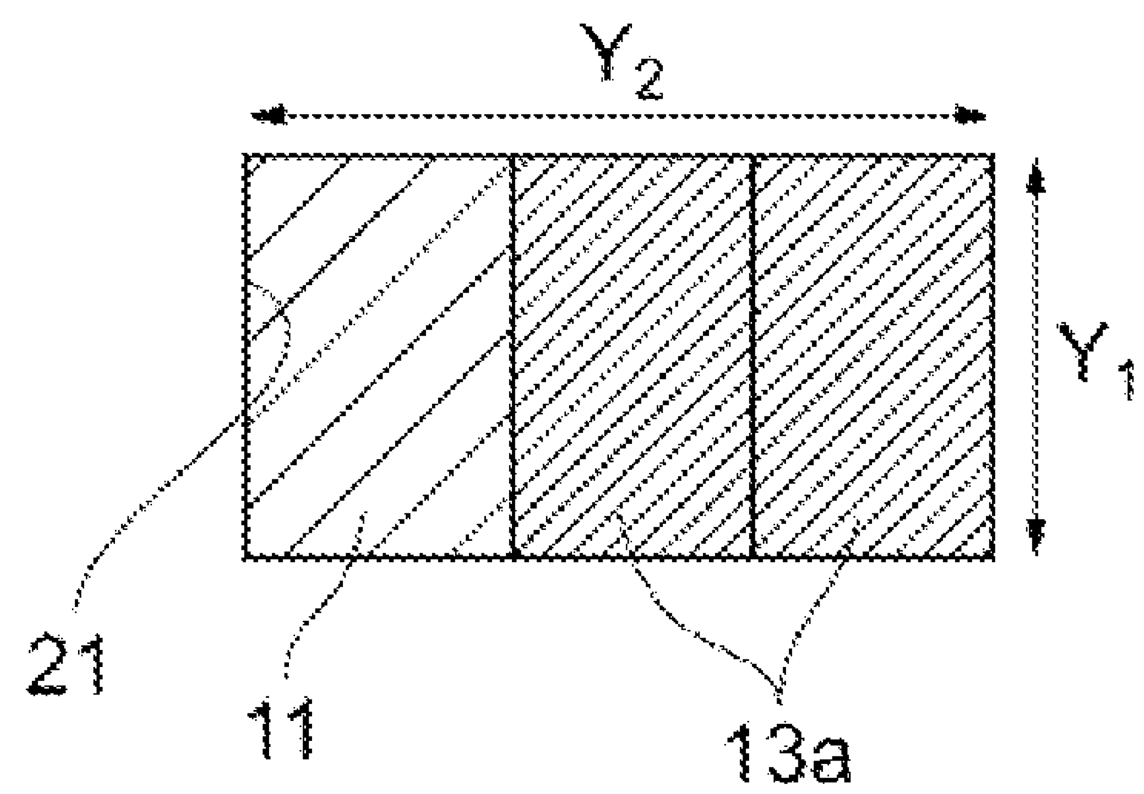


Fig. 3B

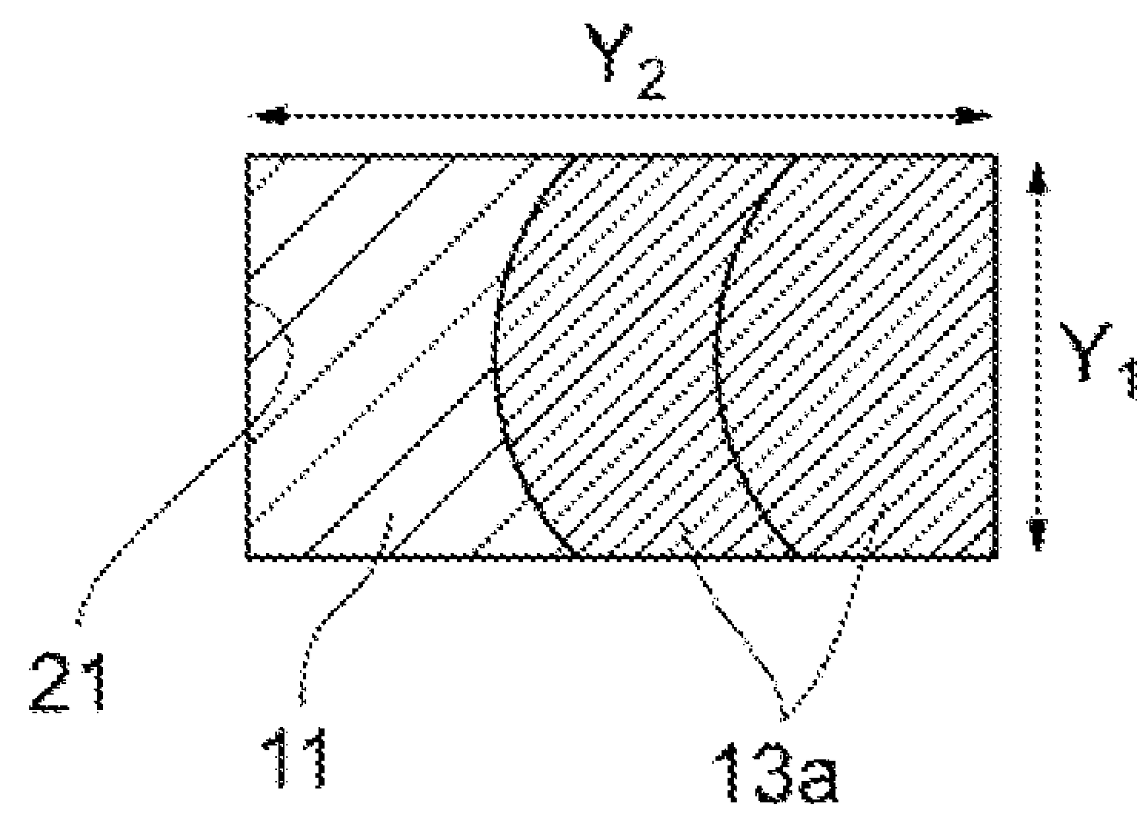


Fig. 3C

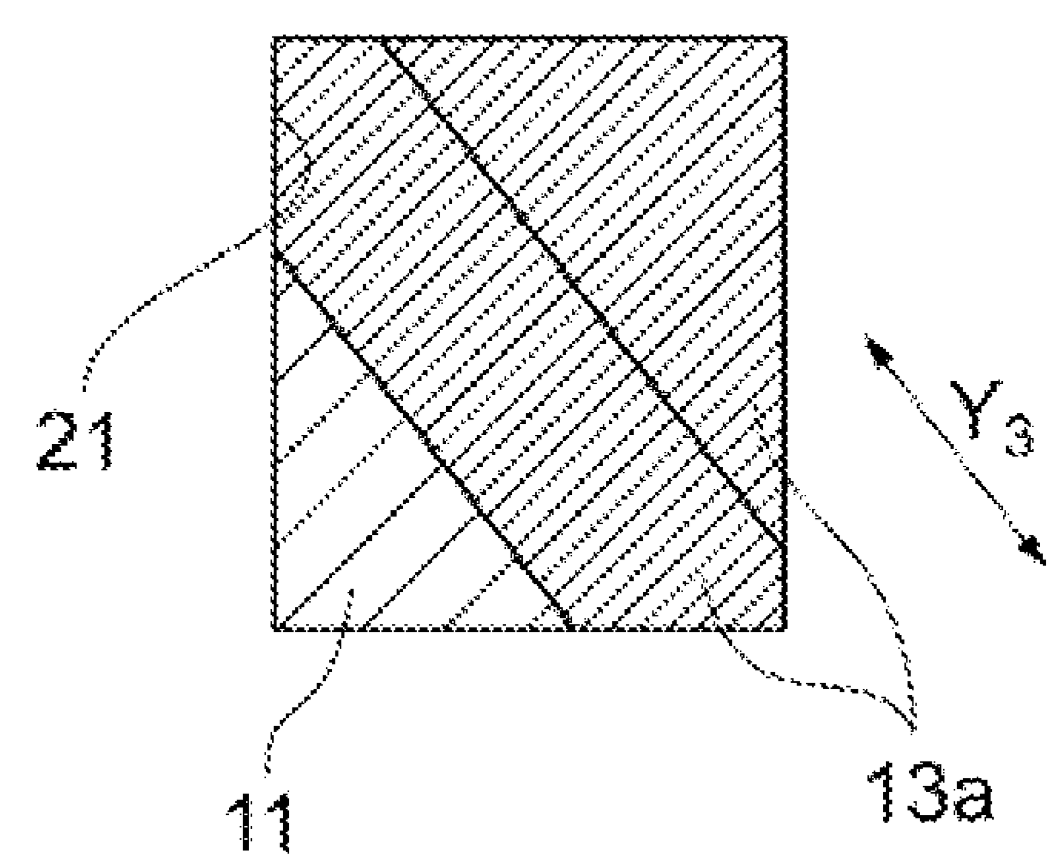


Fig. 4A

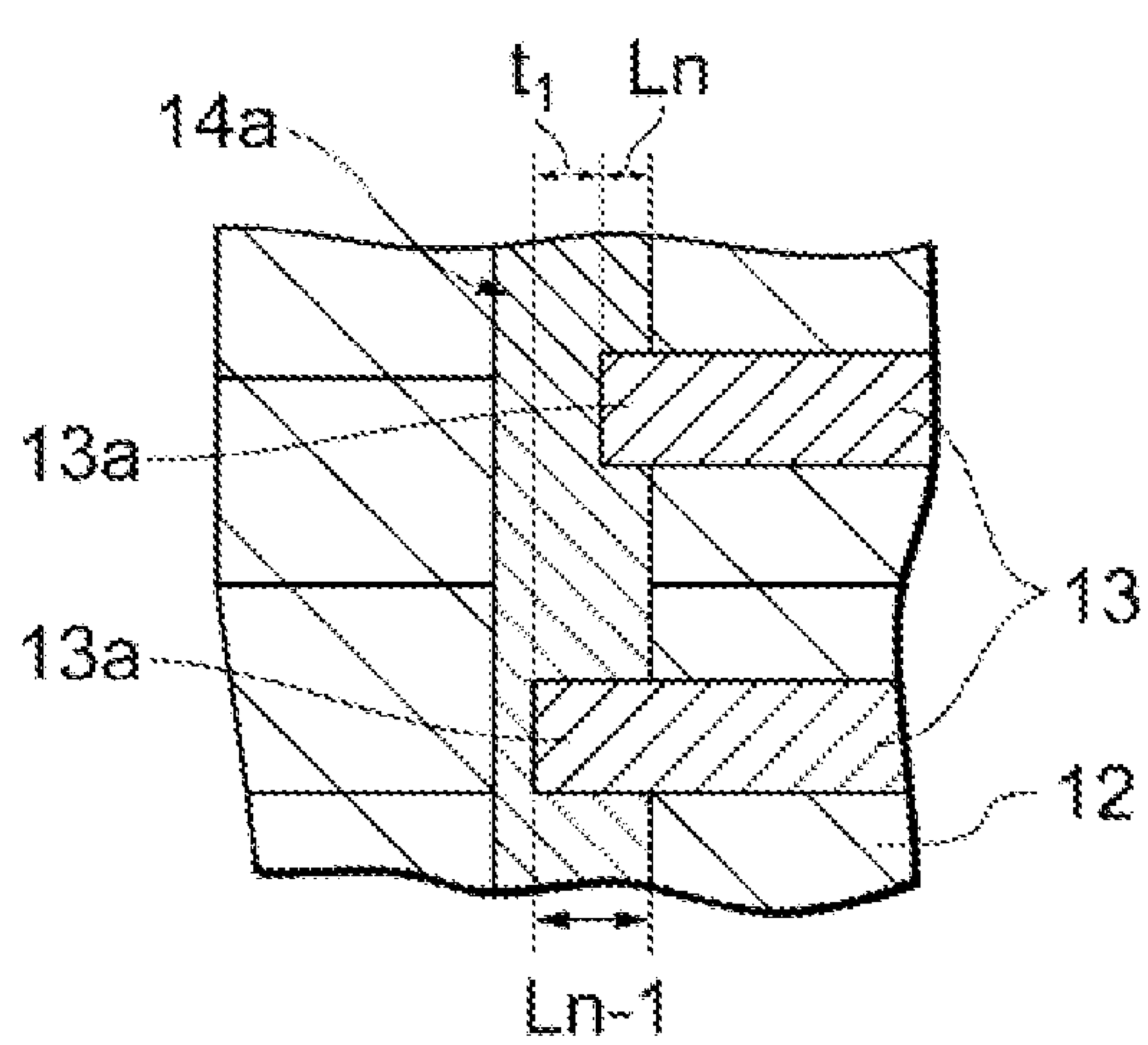


Fig. 4B

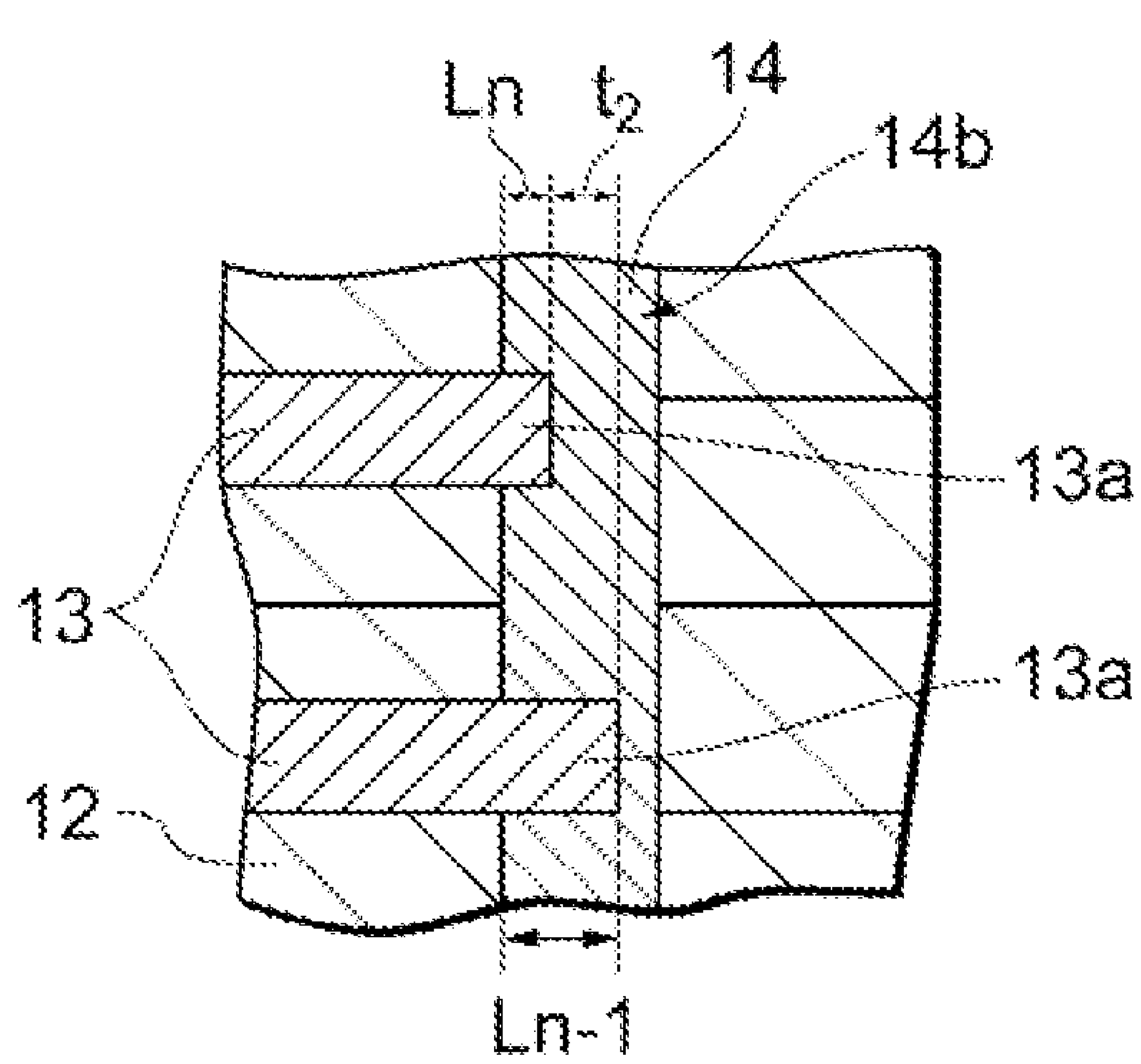


Fig. 5A

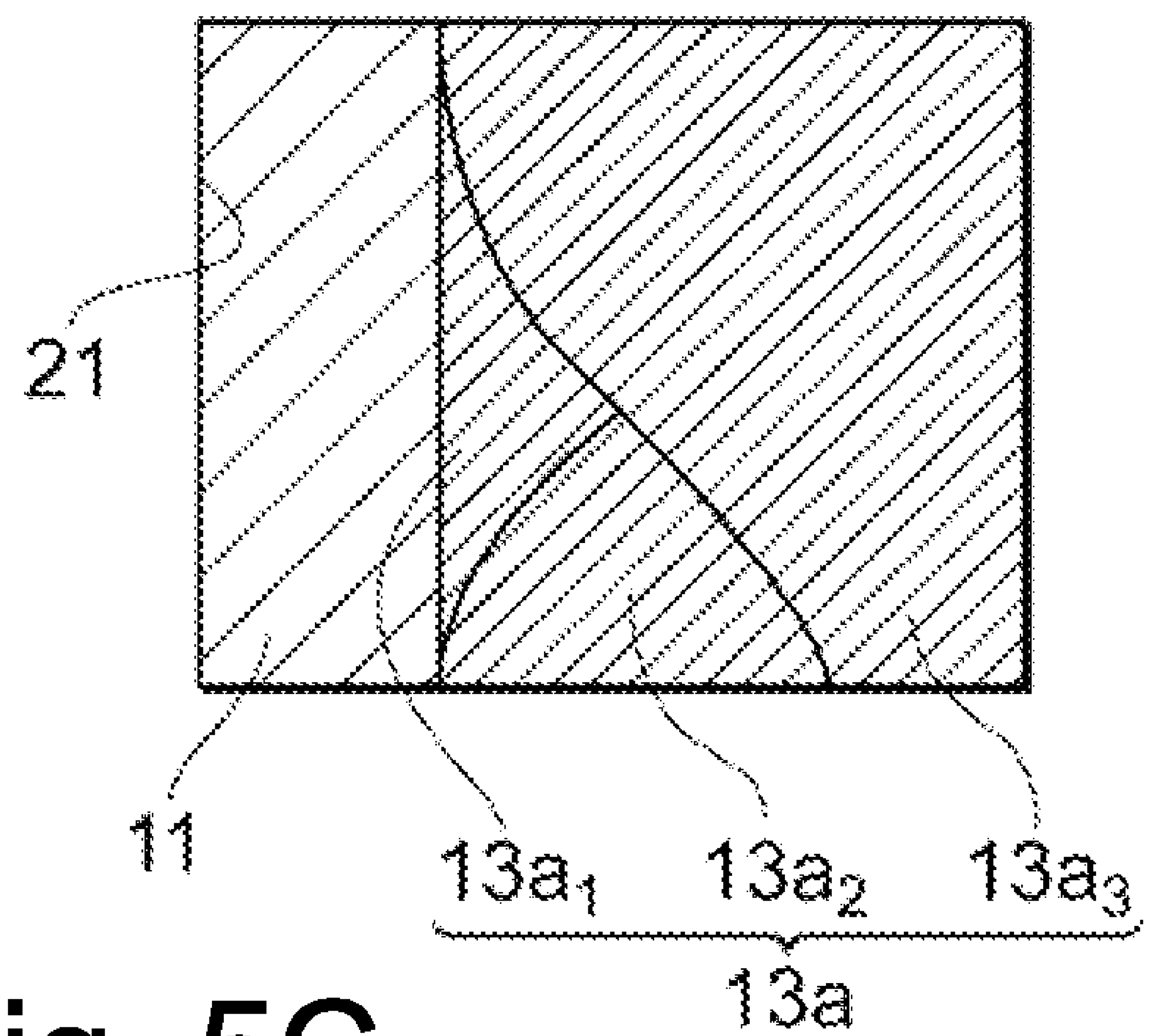


Fig. 5B

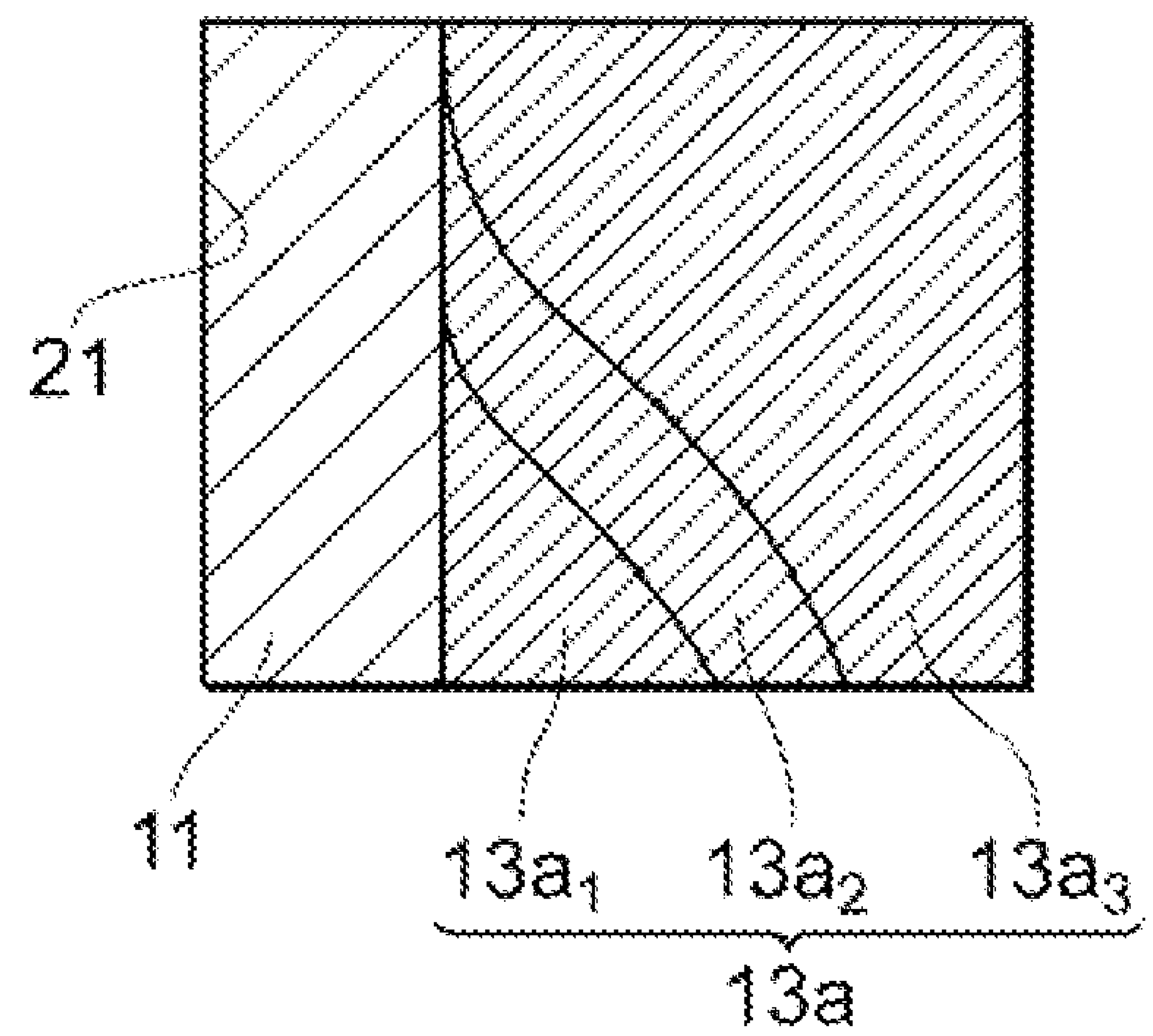
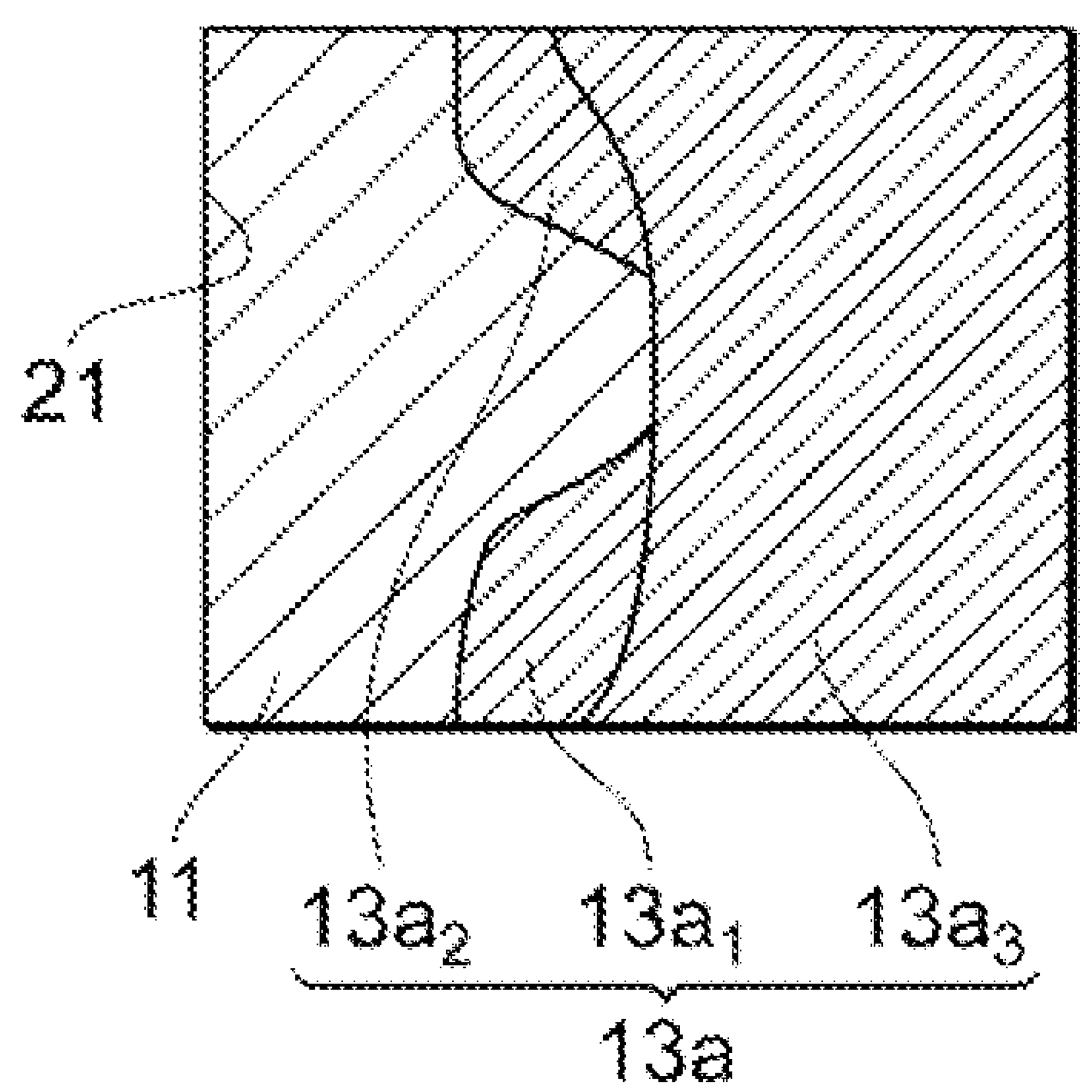


Fig. 5C



THIN FILM CAPACITOR

TECHNICAL FIELD

The present invention relates to a thin film capacitor.

BACKGROUND

Like a thin film capacitor described, for example, in patent related document 1, dielectric body layers and internal electrode layers are alternately laminated and form a multilayer body constituting multiple layers, and configuration where a portion of this multilayer body is exposed and is connected to a terminal electrode is known.

PRIOR RELATED DOCUMENT

Patent Related Document 1: Japanese Laid-Open Patent Application No. 2011-77151

SUMMARY

However, in the thin film capacitor described in Japanese Laid-Open Patent Application No. 2011-77151, end parts of the internal electrode layers are exposed so as to protrude from the dielectric body layers viewed from the lamination direction of a multilayer body and the connection with the connection electrode is secured. Consequently, especially out of variations of the protrusion amount, when the protrusion amount of the internal electrode layer at the lower side (under electrode side) viewed from the lamination direction is smaller than that of the internal electrode layer at the upper side, the connection between the lower internal electrode layer and the connection electrode easily becomes unstable. Therefore, a situation easily occurs where capacitance, which is presumed in the design stage, cannot be sufficiently obtained.

The present invention has been accomplished by taking these drawbacks above into consideration. The object is to provide a thin film capacitor that enables improvement of the stability of the electric connection between the internal electrode layers and the connection electrode.

In order to solve the drawbacks, a thin film capacitor of the present invention includes an under electrode, a plurality of dielectric body layers and a plurality of internal electrode layers that are alternately laminated on the under electrode, the internal electrode layers respectively including protrusion parts that each protrude from the dielectric body layers viewed in the lamination direction, and connection electrodes to which at least a portion of each of the protrusion parts contacts. Assuming that protrusion amounts of the protrusion parts of the internal electrode layers that are connected to the same connection electrode are regarded as L, a protrusion amount L_n of a protrusion part of n^{th} ($n \geq 2$) internal electrode layer from the under electrode side is smaller than another protrusion amount L_{n-1} of another protrusion part of $(n-1)^{th}$ internal electrode layer.

Further, it is preferred for the thin film capacitor that the protrusion amounts L_n and L_{n-1} of the protrusion parts of the internal electrode layers satisfy $L_{n-1}-L_n \geq 2$ μm. With this design, the stability of the electric connection between the internal electrode layers and the connection electrode is further improved. Then, when the stability of the electric connection is improved, the product yield becomes better.

Further, it is preferred that the connection electrodes include at least a first connection electrode and a second connection electrode, and assuming that an average of a protrusion amount difference of the protrusion amount L_n and the protrusion amount L_{n-1} of the protrusion parts of the internal electrode layers connected through the first connection electrode is regarded as t_1, and another average of the protrusion amount difference of the protrusion amount L_n and the protrusion amount L_{n-1} of the protrusion parts of the internal electrode layers connected through the second connection electrode is regarded as t_2, t_1 and t_2 are different. According to such configuration, it is difficult for cracks due to stress to occur, and the stability of the electric connection with the connection electrode is further improved.

Further, it is preferred for the thin film capacitor that the first connection electrode is connected to the under electrode, the second connection electrode is not connected to the under electrode, the averages t_1 and t_2 of the protrusion amount differences are in a relationship of $t_1 < t_2$. According to such configuration, because the electric resistance of the internal electrode layers connected by the second connection electrode becomes further closer to the electric resistance with the internal electrode layers connected by the first connection electrode that is connected to the under electrode, the stability of the electric resistance is further improved.

According to the thin film capacitor relating to the present invention, it becomes possible to improve the stability of the electric connection between the internal electrode layers and the connection electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A and **1**B are schematic cross-sectional views showing a structure of a thin film capacitor relating to an embodiment of the present invention.

FIGS. **2**A to **2**F are schematic cross-sectional views showing a method for manufacturing the thin film capacitor relating to the embodiment of the present invention.

FIGS. **3**A to **3**C are schematic diagrams showings typical configurations regarding an opening and an end part of the internal electrode layer in the thin film capacitor relating to the embodiment of the present invention.

FIGS. **4**A and **4**B are schematic views where the schematic cross-sectional view of the connection portion between either a first connection electrode or a second connection electrode and the internal electrode layers, out of the connection electrodes of the thin film capacitor in FIG. **1**A.

FIGS. **5**A to **5**C are schematic diagrams showing configurations regarding the opening and the end part of the internal electrode layers in the thin film capacitor relating to the embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS

Hereafter, preferred embodiments of the present invention are described. However, the present invention shall not be limited to the embodiments below. Furthermore, the same or the similar elements are marked with the same symbols, and if the description is redundant, such description will be omitted.

FIGS. **1**A and **1**B are schematic cross-sectional views showing a structure of the thin film capacitor relating to the present embodiment, respectively. FIG. **1**A shows a schematic cross-sectional view showing structures of two thin film capacitors relating to the present embodiment. Thin film capacitor **10** is configured by including an under electrode **11**, two or more dielectric body layers **12** laminated onto this under electrode **11**, internal electrode layers **13** laminated in between the dielectric body layers **12**, connection electrodes **14** that are electrically connected to the internal electrode layers **13**, a passivation layer **15** as a surface protective film, and terminal electrodes **16**. For comparison, FIG. **1**A illustrates aggregate composed of two thing film capacitors **10**. This aggregate can be divided into one thin film capacitor **10** by singulation.

The dielectric body layers **12** and the internal electrode layers **13** form a multilayer body by alternate lamination. Furthermore, in FIG. **1**A, although the state of the lamination with the dielectric body layers **12** and the internal electrode layers **13** is simplified by including six layers of the dielectric body layers **12** and five layers of the internal electrode layers **13**, in the thin film capacitor **10** of the present embodiment, several hundreds of the dielectric body layers **12** and the internal electrode layers **13** can form a multilayer body.

FIG. **1**B shows a schematic view where the schematic cross-sectional view of the connection portion between the internal electrode layers **13** and the connection electrode **14** in the thin film capacitors **10** shown in FIG. **1**A is enlarged. The internal electrode layers **13** have a protrusion part **13***a* that protrudes toward the connection electrode **14** (in the X-direction) from the dielectric body layer **12** viewed from the lamination direction, respectively. In addition, at least a portion of the protrusion part **13***a* is connected to the protrusion part **13***a* and the connection electrode **14**. In other words, the connection electrode **14** is electrically connected to the internal electrode layer **13** through the surface and end surface of the internal electrode layer included in the protrusion part **13***a* of this internal electrode layer **13**, respectively. In order to improve the connection stability of these internal electrode layers **13**, it has been found that connection can be assured with the configuration below, in the thin film capacitors of the present embodiment.

In the protrusion part **13***a* of the internal electrode layer **13**, the direction of protrusion from the dielectric body layer **12** toward the connection electrode **14** is one of two directions viewed from the lamination direction, and the other alternately protrudes toward the connection electrode **14** in two directions. In other words, with a connection electrode **14***a* (**14***a* in FIG. **1**A), which is one of the connection electrodes **14**, the under electrode **11** and 1^{st}, 2^{nd} . . . internal electrode layers **13** from the lower side are connected, and with a connection electrode **14***b* (**14***b* of FIG. **1**A), which is the other one of the connection electrode **14**, the 1^{st}, 2^{nd} internal electrode layers **13** from the lower side are connected. The connection electrodes **14** include the protrusion parts **13***a*. For comparison, the internal electrode layers **13** connected to the connection electrode **14***a* are connected to the under electrode **11** and the odd-numbered, such as 1^{st}, 3^{rd} . . . internal electrode layers **13**, from the lower side viewed from the entire internal electrode layers **13** of the thin film capacitor **10**. Similarly, the other connection electrode **14***b* is connected to the even-numbered, such as 2^{nd}, 4^{th} . . . internal electrode layers **13**, from the under electrode side viewed from the entire internal electrode layers **13** of the thin film capacitor **10**.

In addition, in FIG. **1**A, in the thin film capacitors **10**, a pair of connection electrodes **14** has at least two connection electrodes **14** one of which is the first connection electrode **14***a* and the other of which is the second connection electrode **14***b*. The first connection electrode **14***a* in FIG. **1**A makes contact with (is connected to) the under electrode **11**. The other second connection electrode **14***b* in FIG. **1**A does not make contact with (is not connected to) the under electrode **11**.

Then, particularly in the present embodiment, the protrusion parts **13***a* of the internal electrode layers **13** are configured so as to satisfy the conditions below. In other words, regarding a protrusion amount L of the protrusion parts **13***a* toward the dielectric body layers **12** in the internal electrode layers **13** connected to the connection electrode **14** (for example, **14***a* in FIG. **1**A), when a protrusion amount of the protrusion **13***a* of the n^{th} ($n \geq 2$) internal electrode layer **13** counting from the under electrode **11** is regarded as L_n and a protrusion amount of the protrusion **13***a* of the $(n-1)^{th}$ internal electrode layer **13** is regarded as L_{n-1}, these satisfy the following conditional expression (1):

$$L_n < L_{n-1} \quad (1)$$

Furthermore, the protrusion amount L of the protrusion part **13***a* indicates maximum length of the portion where the protrusion part **13***a* makes contact with (is connected to) the connection electrode **14**.

The protrusion amount L_n of the protrusion part **13***a* of the n^{th} ($n \geq 2$) internal electrode layer **13** counting from the under electrode **11** is preferably smaller by 2 μm or more than the protrusion amount L_{n-1} of the protrusion part **13***a* of the $(n-1)^{th}$ internal electrode layer **13**. In other words, for the internal electrode layers **13** connected to the same connection electrode **14**, the difference between the protrusion amount L_n of the n^{th} ($n \geq 2$) internal electrode layer **13** counting from the under electrode **11** and the protrusion amount L_{n-1} of the $(n-1)^{th}$ internal electrode layer **13** is preferably 2 μm or more. That is, it is preferable that the protrusion amounts L_n and L_{n-1} satisfy the following expression (2):

$$L_{n-1} - L_n \geq 2\ \mu m \quad (2)$$

This enables to sufficiently secure the connection area of the $(n-1)^{th}$ internal electrode layer **13** and the connection electrode **14**, and to further stabilize the connection status.

For the internal electrode layers **13** connected to the same connection electrode **14**, when the protrusion amount L_n of the n^{th} ($n \geq 2$) internal electrode layer **13** counting from the under electrode **11** is greater than the protrusion amount L_{n-1} of the $(n-1)^{th}$ internal electrode layer **13**, the n^{th} internal electrode layer **13** is in a hood-like shape (shape to overlay the $(n-1)^{th}$ internal electrode layer **13** when observing toward the under electrode **11**). Consequently, it is believed that a connection area that is enough to stabilize the electric connection between the $(n-1)^{th}$ internal electrode layer **13** and the connection electrode **14** is not secured, and that the connection status becomes unstable.

Further, for the internal electrode layers **13** connected to the same connection electrode **14**, when the protrusion amount L of the n^{th} ($n \geq 2$) internal electrode layer **13** counting from the under electrode **11** is the same as the protrusion amount L_{n-1} of the $(n-1)^{th}$ internal electrode layer **13**, the n^{th} internal electrode layer **13** shall becomes shaped to substantially overlap the $(n-1)^{th}$ internal electrode layer **13** when observing toward the under electrode **11**. Consequently, the $(n-1)^{th}$ internal electrode **13** is connected to the connection electrode **14** only in the vicinity of the end part, and it is believed that a connection area that is enough to stabilize the electric connection cannot be secured, and the connection status becomes unstable.

For the internal electrode layers **13** connected to the same connection electrode **14**, the difference between the protrusion amount L_n of the n^{th} ($n \geq 2$) internal electrode layer **13** counting from the under electrode **11** and the protrusion amount L_{n-1} of the $(n-1)^{th}$ internal electrode layer **13** is preferably 2 μm or more, and more certain connectivity can be obtained. However, if the difference in the protrusion amount is too great, it becomes necessary to have wider connection electrodes **14**. In other words, in the thin film capacitor **10**, a ratio of an area occupied by the connection electrodes **14** becomes greater. Consequently, a portion for obtaining capacitance in the thin film capacitor **10** becomes smaller, and as a result, the capacitance as the thin film capacitors **10** is reduced. Consequently, the difference $L_{n-1}-L_n$ between L_n and L_{n-1} is preferably approximately 2 μm to 50 μm, and is further preferably approximately 2 μm to 10 μm.

With the protrusion amount L of the protrusion parts **13***a* of the internal electrode layers **13** having connection with the connection electrode **14**, the difference between the protrusion amount L_n of the n^{th} (n≥2) internal electrode layer **13** counting from the under electrode **11** and the protrusion amount L_{n-1} of the $(n-1)^{th}$ internal electrode layer **13** can be indicated as t. For example, for the difference t of this protrusion amounts, because there are a plurality of layers of the internal electrode layers **13**, there are a plurality of differences t in one connection electrode **14**, the average of the differences of the protrusion amounts can be an average t.

FIGS. **4**A and **4**B show schematic views where the schematic cross-sectional view of a connection portion between the internal electrode layers **13** and the first connection electrode **14***a* or the second connection electrode **14***b* out of the connection electrodes **14** of the thin film capacitors **10** in FIG. **1**A is enlarged, respectively. In FIG. **4**A, for the internal electrode layers **13** at positions to be connected to the first connection electrode **14***a*, a difference between the $(n-1)^{th}$ protrusion amount L_{n-1} and the n^{th} protrusion amount L_n is regarded as t**1**. In this case, in the drawing, a single protrusion amount difference is illustrated as t**1**, but in the case of having multiple layers, this can be regarded as an average t**1** of the protrusion amount differences. In addition, in FIG. **4**A, for the internal electrode layers **13** at positions to be connected to the second connection electrode **14***b*, a difference between the $(n-1)^{th}$ protrusion amount L_{n-1} and the n^{th} protrusion amount L_n is regarded as t**2**. In this case, in the drawing, a single protrusion amount difference is illustrated as t**2**, but in the case of having multilayer, this can be regarded as an average t**2** of the protrusion amount differences.

At this time, it is preferable that the average t**1** of protrusion amount differences and the average t**2** of protrusion amount differences are different. If the averages t**1** and t**2** of the protrusion amount differences are different, it becomes difficult for the stress to the connection between the connection electrodes **14** and the internal electrode layers **13** to be concentrated to the center of the thin film capacitors **10**, and there is an effect where it is difficult for cracks or peel-off attributable to the stress to occur. In other words, according to such configuration, it is difficult for cracks and peel-off due to the stress to occur, and the stability of the electric connection with the connection electrodes can be further improved. For this relationship, even if errors due to the manufacturing variation are included, [such configuration] has the effect where it is difficult for the cracks or peel-off to occur.

In addition, in the thin film capacitors **10**, compared to the average t**1** of the protrusion amount differences of the first connection electrode **14***a* connected to the under electrode, the average t**2** of the protrusion amount differences of the second connection electrode **14***b* is preferably greater, i.e., the relationship t**1**<t**2** is preferable. According to such configuration, because the electric resistance of the internal electrode layers connected through the second connection electrode and that with the internal electrode layers connected through the first connection electrode connected to the under electrode are further closer, the stability of the electric resistance can be further improved. In addition, the characteristic of equivalent series resistance (ESR) of the thin film capacitors **10** also tends to be improved, and it is further preferable.

The internal electrode layers **13** are preferably configured by containing an inexpensive base metal material as a main component for the purpose of cost reduction, and since the internal electrode layers **13** are sintered along with the dielectric body layers **12**, it is preferably configured particularly with Ni as a main component. If Ni is contained as a main component and the protrusion amount satisfies the conditions above, the stability of the connection is particularly effectively improved. It is believed that this is because the crystal grains of the Ni internal electrode layers and the protrusion amount are in the most suitable state. Furthermore, the internal electrode layers **13** can be configured so as to contain at least, for example, one of Ni, Pt, Pd, Ir, Ru, Rh, Re, Os, Au, Ag, Cu, IrO_2, RuO_2, $SrRuO_3$ and $LaNiO_3$. It is preferable that the thickness of the internal electrode layer **13** is approximately 100 to 800 nm.

The under electrode **11** can be configured by containing, for example, at least one of Ni, Pt, Pd, Ir, Ru, Rh, Re, Os, Au, Ag, Cu, IrO_2, RuO_2, $SrRuO_3$ and $LaNiO_3$. The film thickness of the under electrode is preferably 50 to 2,000 nm. Further, the under electrode **11** and a substrate can be made of the same material. In such case, to reduce cost, inexpensive base metal, such as Ni, Cu or Al, an alloy thereof as a main component, stainless steel, or Inconel (registered trademark) is preferable, and Ni foil is particularly preferable. The film thickness in the case of using the same material for the under electrode **11** and the substrate is preferably 5 μm to 500 μm. In the present embodiment, the Ni foil is used for the under electrode **11**, and this combines a function as a retainer member to retain the dielectric body layer **12** and another function as a substrate to form the dielectric body layer **12**. In addition, if the Ni foil is used, in the case of sintering after laminating the internal electrode layers **13** and the dielectric body layers **12**, cracks or peel-off hardly occurs to the multilayer body. Therefore, in the thin film capacitor of the present embodiment, in order to control the protrusion amount, it is preferable to minimize cracks or peel-off in the multilayer. Thus, the under electrode **11** relating to the present embodiment preferably has a configuration to double as a substrate, such as a metal foil, and as an electrode. However, a structure with substrate/electrode film including a substrate made of Si or alumina and a substrate made of a metal film may be used as the under electrode **11**.

For the dielectric body layer **12**, perovskite oxides, such as BT (i.e., barium titanate: $BaTiO_3$), BST (i.e., barium strontium titanate: $(BaSr)TiO_3$), ST (i.e., strontium titanate: $SrTiO_3$), CZ (i.e., calcium zirconate: $CaZrO_3$), perovskite type oxide, such as $BaSr)(TiZr)O_3$, $BaTiZrO_3$, or the like, are preferably used. The dielectric body film **12** can contain one or more of these oxides. It is preferable that the film thickness of the dielectric body layer **12** is approximately 100 to 800 nm.

The connection electrode **14** may be made of an inexpensive base metal material, such as Cu, but one configured by using Ni, Pt, Pd, Ir, Ru, Rh, Re, Os, Au, Ag or Ir at least in a portion is preferable, and one constructed by using Ni as a main component is particularly preferable. Inexpensive base metal, such as Cu, easily damages the internal electrode layers **13** and the dielectric body layer **12** due to passage of oxygen in the connection region, and the connectivity may also become poor. Depending upon the required reliability, such base metal may not be able to be used. Furthermore, the connection electrode **14** can have a multi-layer structure, for example, with Ni/Cu. In this case, a method to ensure contact in the Ni layer and to supplement the conductivity at the Cu side is particularly preferable. In any event, configuration using Ni, Pt, Pd, Ir, Ru, Rh, Re, Os, Au, Ag or Ir at least in a portion as a main component is preferable, and the configuration using Ni at least in a portion as a main component is particularly preferable.

The passivation film **15** may be made of an insulating resin, such as polyimide resin, epoxy resin, phenol resin, benzocyclobutene resin, polyamide resin or fluorine contained resin.

The terminal electrode **16** is preferably configured by containing Cu as a main component. Furthermore, a layer of Au, Sn or Pd may be established in the external layer of the terminal electrode **16**.

Next, with reference to FIGS. **2**A to **2**F and FIGS. **3**A to **3**C, a method for manufacturing the thin film capacitor **10** is explained. As an example, FIGS. **2**A to **2**F illustrate aggregate composed of two thin film capacitors **10**. These can be divided into one thin film capacitor **10** by singulation.

At first, as shown in FIG. **2**A, film formation of the dielectric body layers **12** and film formation of the internal electrode layers **13** using a mask are alternately repeated on the under electrode **11**, and a multilayer body is formed. At this time, for the internal electrode layers **13**, the films are formed using a mask so as to alternately displace the film formation position at predetermined amplitude per layer. Further, in the region connected to the terminal electrode, mask shape is specified so as to recess the end portions in the upper layer internal electrode layers **13**.

Next, as shown in FIG. **2**B, wet etching is applied from the surface position at the opposite side of the under electrode **11** in the multilayer body so as to expose the protrusion parts **13***a* of the internal electrode layers **13**, and openings **21** are formed. At this time, etching liquid (etchant) that etches a dielectric body but that does not etch an electrode layer is used. Specifically, for example, when the dielectric body film is BT, BST or ST, a preferred etchant is a hydrochloric acid+ammonium fluoride solution. Further, when the dielectric body film is CZ, the preferred etchant is a sulfuric acid+ammonium fluoride solution. Herein, the protrusion amount L of the protrusion part **13***a* exposed to the opening **21** by wet etching means maximum length of the protrusion part **13***a* in the opening **21**.

FIGS. **3**A to **3**C show typical schematic shapes of the protrusion parts **13***a* of the internal electrode layers **13** when an opening **21** is observed toward the under electrode **11**, after the roughly-rectangular opening **21** shown in FIG. **2**B is formed. For example, as shown in FIG. **3**A and FIG. **3**B, in the opening **21** at the time of observing toward the under electrode **11**, if the end part of the protrusion parts **13***a* are aligned in the longer side direction (aligned so as to parallelize a shorter side direction **Y1** and the end parts of the protrusion parts **13***a*) out of the shorter direction **Y1** and the longer side direction **Y2** of the roughly-rectangular opening **21**, when the number of laminations is increased, it becomes possible to sufficiently establish (expose) the protrusion part **13***a* in each internal electrode layer **13** within the opening **21**. In addition, as shown in FIG. **3**C, if the end parts of the protrusion parts **13***a* are parallel with a diagonal direction **Y3** of the roughly-rectangular opening **21** upon observing toward the under electrode **11**, even when the number of laminations is increased, because more area can be secured with regard to each protrusion part **13***a* within the opening **21**, it becomes possible to more certainly expose the internal electrode layers **13**.

Next, as shown in FIG. **2**C, a connection layer is formed in the openings **21**. For example, a film is formed throughout the entire surfaces and end surfaces of the protrusion parts **13***a* of the internal electrode layers **13** along the inner walls of the openings so as not to cause any voids, by sputtering.

Then, the connection electrodes **14** are molded by patterning (FIG. **2**D) and the passivation film **15** is formed if necessary (FIG. **2**E). Then, the terminal electrodes **16** are further formed so as to connect to the connection electrodes **14** by seed film formation and plating treatment (FIG. **2**F).

Thus, according to the thin film capacitor **10** relating to the present embodiment, because the internal electrode layers **13** and the connection electrodes **14** are connected through at least a part of the surface and end surfaces of the internal electrode layers **13** contained in the protrusion parts **13***a* of the internal electrode layers **13**, a contact area of both is increased, and the connection status is stabilized. In addition, in the internal electrode layers **13** connected through the same connection electrode, if the protrusion amount L_n of the protrusion **13***a* of the n^{th} ($n \geq 2$) internal electrode layer **13** counting from the under electrode **11** is designed to be smaller than the protrusion amount L_{n-1} of the protrusion **13***a* of the $(n-1)^{th}$ internal electrode layer **13**, the protrusion amount L of the protrusion parts **13***a* appropriately ranges so as to be suitably connected to the connection electrodes **14**, and the connection status between the internal electrode layers **13** and the connection electrodes **14** can be further stabilized. As a result, it becomes possible to improve the electric connection between the internal electrode layers **13** and the connection electrodes **14**. Then, when the connection status is stabilized, product yield is improved and the reliability is also improved.

In addition, from the viewpoint to stabilize the connection status by increasing the contact area between the internal electrode layers **13** and the connection electrodes **14**, a portion of the protrusion part **13***a* of each internal electrode layer **13** in the opening **21** preferably has a relationship where the protrusion amount L_n of the protrusion **13***a* of the n^{th} ($n \geq 2$) internal electrode layer **13** counting from the under electrode **11** is smaller than the protrusion amount L_{n-1} of the protrusion **13***a* of the $(n-1)^{th}$ internal electrode layer **13**.

In other words, the protrusion parts of the internal electrode layers connected to the same connection electrode out of the connection electrodes are viewed from the lamination direction toward the under electrode, at least a portion of the protrusion part of the $(n-1)^{th}$ ($n \geq 2$) internal electrode layer counting from the under electrode side is preferably exposed from the protrusion parts of the n^{th} internal electrode layer.

FIGS. **5**A to **5**C show schematic views where at least a portion of the protrusion part of the $(n-1)^{th}$ ($n \geq 2$) internal electrode layer counting from the under electrode side is exposed from the protrusion parts of the n^{th} internal electrode layer when viewed from the lamination direction toward the under electrode. In FIGS. **5**A to **5**C, the shape of the protrusion part **13***a* of the internal electrode layers **13** in another embodiment in the case of observing the opening **21** toward the under electrode **11** after the opening **21** is formed when the internal electrode layers contain six layers is illustrated. FIGS. **5**A to **5**C illustrate the protrusion part **13***a* of the internal electrode layer **13** the closest to the under electrode **11** side from the under electrode **11** toward the lamination direction as a protrusion part $\mathbf{13}a_1$, the protrusion part **13***a* of the 2^{nd} internal electrode layer **13**, which is next, as $\mathbf{13}a_2$, and the protrusion part **13***a* of the 3^{rd} internal electrode layer **13**, which is next, as $\mathbf{13}a_3$. In the protrusion parts $\mathbf{13}a_1$, $\mathbf{13}a_2$ and $\mathbf{13}a_3$, as shown in FIGS. **5**A to **5**C, at least a portion of all the protrusion parts $\mathbf{13}a_1$, $\mathbf{13}a_2$ and $\mathbf{13}a_3$ of the internal electrodes **13** to be connected to the connection electrode **14** of the opening **21** is visible within the opening **21** upon observing toward the under electrode **11**. When the number of laminations is increased, it becomes possible to sufficiently establish (expose) the protrusion part **13**a in each internal electrode layer **13** within the opening **21** without expanding the opening **21**.

For comparison, in FIG. **5**A and FIG. **5**B, although the maximum protrusion amount L of the protrusion parts **13**a_1, **13**a_2 and **13**a_3 is the same, compared to the maximum protrusion amount L_1 of the protrusion part **13**a_1 of the internal electrode **13** the closest to the under electrode **11** side, the maximum protrusion amount L_2 of the protrusion part **13**a_2 of the 2^{nd} internal electrode **13**, which is next, has a smaller region. Then, compared to the maximum protrusion amount L_2 of the protrusion part **13**a_2 of the 2^{nd} internal electrode **13**, the maximum protrusion amount L_3 of the protrusion part **13**a_3 of the 3^{nd} internal electrode **13**, which is next, has a smaller region, and, is in a relationship to have a smaller region than the maximum protrusion amount L_1 of the protrusion part **13**a_1 and the maximum protrusion amount L_2 of the protrusion part **13**a_2 With this relationship, the protrusion part **13**a is sufficiently established and exposed in each internal electrode layer **13** within the opening **21**.

In FIGS. **5**A, **5**B and **5**C, the first connection electrode **14**a is illustrated, but the effect can be obtained similarly with this construction even in the second connection electrode **14**b. In addition, regarding this relationship, even when errors are included due to manufacturing variation, the similar effect can be obtained.

Film formation of the dielectric body layers **12** and mask film formation of the internal electrode layers **13** are alternately repeated on the under electrode **11**, and a multilayer body is formed. At this time, adjustment can be conducted by changing the shape of the region connected to the connection electrode **14**, which is a mask of the internal electrode layer, i.e., changing the protrusion part **13**a, and by conducting mask film formation.

EXAMPLES

Hereafter, the present invention is further specifically explained with reference to examples. However, the present invention shall not be limited to the embodiments below.

The thin film capacitors shown in FIG. **1** were manufactured and evaluated as Examples 1 to 6 and Comparative Examples 1 to 3.

Examples 1 to 6

In the thin film capacitors **10**, six layers of the dielectric body layers **12** were laminated on the Ni foil under electrode **11** using BT, and the internal electrode layers **13** were laminated using Ni as the first internal electrode layer **13** to the fifth internal electrode layer **13** by alternately sputtering with the dielectric body layers **12**. With this step, the number of layers of the under electrode **11** as the Ni substrate and the dielectric body layer **12** sandwiched by the internal electrode layers **13** becomes five. A pattern shape on the occasion of film formation of the internal electrode layers **13** and thickness of the dielectric body layers **12** were set so as to have approximately 6,000 pF (6 nF) of one layer of the dielectric body layer **12**.

In addition, as shown in FIG. **1**B, for four layers from the second internal electrode layer **13** to the fifth internal electrode layer **13**, in order to satisfy a positional relationship where the internal electrode layers **13** connected by the same connection electrode **14** as smaller protrusion amount in respective order from the under electrode **11** side, their shape was specified using a mask pattern. In other words, the internal electrode layers **13** at the positions to be connected with the connection electrode **14** were arranged so as to position the end part of the fourth internal electrode layer **13** to be closer to the inner side of the end part of the second internal electrode layer **13**, and, so as to position the end part of the fifth internal electrode layer **13** to be closer to the inner side of the end part of the third internal electrode layer **13**, respectively. In other words, the internal electrode layers **13** connected by the same connection electrode **14** were arranged so as to have smaller protrusion amount L of the 2^{nd} internal electrode layer **13** than the protrusion amount L of the 1^{st} internal electrode layer **13** in respective order from the under electrode **11** side.

For the internal electrode layers **13** at positions to be connected with the connection electrode **14**, a difference between the end part of the 4^{th} internal electrode layer **13** and the end part of the 2^{nd} internal electrode layer **13** (for the internal electrode layers **13** connected through the one same connection electrode **14**, the protrusion amount L of the 2^{nd} internal electrode layer **13** is the 1^{st} internal electrode layer) is regarded as t_1, and, a difference between the end part of the 5^{th} internal electrode layer **13** and the end part of the 3^{rd} internal electrode layer **13** (for the internal electrode layers **13** connected through another same connection electrode **14**, the protrusion amount L of the 2^{nd} internal electrode layer **13** is the 1^{st} internal electrode layer) is regarded as t_2, and mask shape was specified so as to have relationships: t_1==t_2=15 μm (Example 1), 10 μm (Example 2), 5 μm (Example 3), 3 μm (Example 4), 2 μm (Example 5) and 1 μm (Example 6) on the mask pattern, and these thin film capacitors **10** to be Examples 1 to 6 were prepared. In other words, t_1 and t_2 correspond to a difference $t(=L_{n-1}-L_n)$ of protrusion amounts of the internal electrode layers **13** shown in FIG. **1**B.

In other words, the difference t_1 between the end part of the 4^{th} internal electrode layer **13** and the end part of the 2^{nd} internal electrode layer **13** is a difference of the protrusion amount in the first connection electrode connected to the under electrode **11**. Then, the difference t_2 between the end part of the 5^{th} internal electrode layer **13** and the end part of the 3^{nd} internal electrode layer **13** is a difference of the protrusion amount in the second connection electrode not connected to the under electrode **11**.

In Examples 1 to 6, after the dielectric body layers **12** and the internal electrode layers **13** were laminated, a resist layer having the openings **21** was formed on a thermally-treated aggregate at a position enabling the connection with the internal electrodes. The shape of the opening **21** was designed to be a rectangle on the mask pattern, and the size was set at 30 μm×40 μm on the mask pattern. Then, the dielectric body layers **12** at the openings **21** were etched using a mixed solution of hydrochloric acid+ammonium fluoride. Due to this etching, the dielectric body layers **12** at the openings **21** were removed, and, the protrusion parts **13**a were formed by realizing the state where end parts of the internal electrode layers **13** protruding from the side walls of the dielectric body layers **12** at the openings **21**. Then, after the resist layer was peeled off, a thermal treatment was applied again. Then, a conductor layer for connection (connection electrode **14**) was formed in the opening **21**. The passivation layer **15** was further formed using polyimide resin, and the terminal electrode **16** was further formed using Cu.

Using such technique, 30 thin film capacitors **10** were manufactured for each of the above described t_1 and t_2 values, and capacitance was measured in these thin film capacitors **10**, and the average values and standard deviations were calculated. In addition, the conductor layer for connection (connection electrode **14**) and the internal electrode layers **13** were cut by focused ion beam (FIB), and 30 each of the t_1 and t_2 values were measured and their averages were regarded as actually-measure t_1 and t_2 values, respectively.

Comparative Example 1

Other than the arrangement of the internal electrode layers **13** where the t_1 value was set at 2 μm and the t_2 value was set at 0, i.e. at positions to be connected with the connection electrode **14** on the mask pattern so as to position the end parts of the 5^{th} internal electrode layer **13** and the 3^{rd} internal electrode layer **13** to be the same, the thin film capacitors **10** were manufactured as similar to Example 1. The capacitance of the thin film capacitor **10** was measured as similar to Example 1, and its mean value and standard deviation were calculated. In addition, similarly, the conductor layer for connection (connection electrode **14**) and the internal electrode layers **13** were cut by FIB, and 30 each of t_1 and t_2 values were measured and their averages were regarded as actually-measure t_1 and t_2 values, respectively.

Comparative Example 2

Other than the arrangement of the internal electrode layers **13** where both the t_1 and t_2 values were set at 0, i.e. at positions to be connected with the connection electrode **14** on the mask pattern so as to position the end parts of the 4^{th} internal electrode layer **13** and the 2^{th} internal electrode layer **13** to be the same and to position the end parts of the 5^{th} internal electrode layer **13** and the 3^{rd} internal electrode layer **13** to be the same, the thin film capacitors **10** were manufactured as similar to Example 1. The capacitance of the thin film capacitor **10** was measured as similar to Example 1, and its mean value and standard deviation were calculated. In addition, the conductor layer for connection (connection electrode **14**) and the internal electrode layers **13** were cut by FIB, and 30 each of t_1 and t_2 values were measured and their averages were regarded as actually-measure t_1 and t_2 values, respectively.

Comparative Example 3

Other than the arrangement of the internal electrode layers **13** where both the t_1 and t_2 values were set at −2 μm, i.e. at positions to be connected with the connection electrode **14** on the mask pattern so as to position the end parts of the 4^{th} internal electrode layer **13** to be outside the 2^{nd} internal electrode layer **13**, and, to position the end parts of the 5^{th} internal electrode layer **13** to be outside and the 3^{rd} internal electrode layer **13**, the thin film capacitors **10** were manufactured as similar to Example 1. The capacitance of the thin film capacitor **10** was measured as similar to Example 1, and its mean value and standard deviation were calculated. In addition, the conductor layer for connection (connection electrode **14**) and the internal electrode layers **13** were cut by FIB, and 30 each of t_1 and t_2 values were measured and their averages were regarded as actually-measure t_1 and t_2 values, respectively.

For Example 1 to 6 and Comparative Example 1 to 3 described above, the mean values and the standard deviation for each of the t_1 and t_2 values are shown in Table 1.

TABLE 1

	t_1 and t_2 Values on Mask Pattern (μm)		Actually-measured t_1 and t_2 Values (μm)		Mean Capacitance	Standard Deviation of Capacitance
	t_1	t_2	t_1	t_2	(nF)	(nF)
Example 1	15	15	14.5	14.8	32.18	3.27
Example 2	10	10	9.9	10.1	32.28	2.64
Example 3	5	5	5.3	5.1	31.87	2.92
Example 4	3	3	2.9	3.0	32.21	3.46
Example 5	2	2	2.1	2.3	32.10	3.24
Example 6	1	1	1.2	0.9	32.07	6.97
Comparative Example 1	2	0	2.1	−0.1	30.58	14.77
Comparative Example 2	0	0	−0.2	−0.1	27.22	18.26
Comparative Example 3	−2	−2	−1.8	−2.1	24.67	19.89

As shown in Table 1, in Examples 1 to 5 where the mask shapes were specified to be t_1=t_2=15, 10, 5, 3, 2 μm, respectively, and where 2.1 to 14.8 μm of protrusion amounts were obtained, it was confirmed to have substantially the same capacitance as the set value (6 nF per layer; 30 nF as thin film capacitor **10**). The standard deviation of the capacitance was substantially 3 nF, and variation was small. Further, in Example 6 where the mask shape was specified to be t_1=t_2=1 μm, and where 0.9 μm and 1.2 μm of protrusion amounts were obtained, it was confirmed to have substantially the same capacitance as the set value, but the standard deviation of the capacitance indicated a slightly greater value approximately at 7 nF. In the meantime, in Comparative Example 1 where the mask shape was specified to be $t_{1=1}$ μm and t_2=0, and where 2.1 μm and −0.1 μm of protrusion amounts, i.e., one was indented, it was confirmed that the capacitance greatly varied. Further, in Comparative Examples 2 and 3 where the mask shape was specified to be t_1=t_2=0 and −2 μm, respectively and where −0.2 μm and −0.1 μm, and, −1.8 μm and −2.1 μm of protrusion amounts, i.e., both were indented, it was confirmed that the mean capacitance was lower than the designed value, and, variation was great.

In other words, the thin film capacitors **10** in Examples 1 to 5 had sufficient capacitance compared to those in the comparative examples, and could reduce less variation in the capacitance, and it was confirmed that stable electric connection between the internal electrode layers **13** and the connection electrodes **14** would become possible.

Further, since the thin film capacitor **10** in Example 6 had slightly greater variation in the capacitance compared to the thin film capacitors in Examples 1 to 5, if the difference of the protrusion amounts in the internal electrode layer **13** was set to 2 μm or greater, it was confirmed that the electric connection between the internal electrode layers **13** and the connection electrodes **14** would be further stable.

In addition, in the thin film capacitors **10** in Examples 1 to 6, the difference in the protrusion amount t_1 between the protrusion amounts L_n and L_{n-1} of the protrusion parts of the internal electrode layers connected through the first connection electrode was different from the difference in the protrusion amount t_2 between the protrusion amounts L_n and L_{n-1} of the protrusion parts of the internal electrode layers connected through the second connection electrode, and any cracks attributable to the stress were not confirmed.

Examples 7 and 8

Except the arrangement of the internal electrode layers **13** so as to position the end part of the 6^{th} internal electrode layer

13 to be inner side the end of the 4^{th} internal electrode layer and to position the end part of the 7^{th} internal electrode layer **13** to be inner side the end of the 5^{th} internal electrode layer, in addition to four layers from the 2^{nd} internal electrode layer **13** to the 5^{th} internal electrode layer **13**, the thin film capacitors were manufactured as similar to Example 1.

For the internal electrode layers **13** positioned to be connected with the connection electrodes **14**, the difference between the end part of the 4^{th} internal electrode layer **13** and the end part of the 2^{nd} internal electrode layer **13** and the difference between the end part of the 6^{th} internal electrode layer **13** and the end part of the 4^{th} internal electrode layer **13** are set at the same t_1, and the difference between the end part of the 5^{th} internal electrode layer **13** and the end part of the 3^{rd} internal electrode layer **13** and the difference between the end part of the 7^{th} internal electrode layer **13** and the end part of the 5^{th} internal electrode layer **13** were set at the same t_2, and the mask shape was specified so as to have $t_1=t_2=15$ μm (Example 7) and $t_1=10$ and $t_2=9$ μm (Example 8), and the thin film capacitors to be Examples 7 and 8 were manufactured.

Comparative Example 4

Other than the arrangement of the internal electrode layers **13** where t_1 and t_2 values were set at 0 μm in Example 7, i.e., positions to be connected to the connection electrode **14** on the mask pattern so as to position the end parts of the 7^{th}, 5^{th} and 3^{rd} internal electrode layers **13** to be the same, and, to position the end parts of the 6^{th}, 4^{th} and 2^{nd} internal electrode layers **13** to be the same, the thin film capacitors were manufactured as similar to Example 7.

In Examples 7 and 8 and Comparative Example 4, the capacitance of the thin film capacitors was measured as similar to Example 1, and its mean value and standard deviation were calculated. In addition, similarly, the conductor layer for connection (connection electrode **14**) and the internal electrode layers **13** were cut by FIB, and the t_1 and t_2 values for the 30 thin film capacitors were measured and their averages were regarded as actually-measured t_1 and t_2 values, respectively. For the differences of the protrusion amounts t_1 and t_2 values, since there were a plurality of layers of the internal electrode layers **13**, a plurality of differences of the protrusion amounts t_1 and t_2 values were averaged per the first or second connection electrode, they were deemed as the average t_1 and t_2 values. For the actually measured values, the average values were deemed as the average t_1 and t_2 values. A mean value and a standard deviation of the capacitance on this occasion were similarly measured. Results are shown in Table 2.

TABLE 2

	t_1 and t_2 Values on Mask Pattern (μm)		Actually-measured t_1 and t_2 Values (μm)		Mean Capacitance	Standard Deviation of Capacitance
	t_1	t_2	t_1	t_2	(nF)	(nF)
Example 7	15	15	14.5	14.8	40.23	4.09
Example 8	10	9	9.9	9.1	40.35	3.30
Comparative Example 4	0	0	−0.1	0	34.03	22.83

The thin film capacitors in Examples 7 and 8 had sufficient capacitance, and could reduce less variation in the capacitance, and it was confirmed that a stable electric connection between the internal electrode layers **13** and the connection electrodes **14** would become possible.

In addition, in Examples 7 and 8, the difference in the protrusion amount t_1 between the protrusion amounts L_n and L_{n-1} of the protrusion parts of the internal electrode layers connected through the first connection electrode was different from the difference in the protrusion amount t_2 between the protrusion amounts L_n and L_{n-1} of the protrusion parts of the internal electrode layers connected through the second connection electrode. No cracks attributable to the stress were confirmed in all obtained thin film capacitors.

A characteristic of ESR was measured in the thin film capacitors of Examples 7 and 8, a lower value was obtained in Example 8 than that in Example 7.

Example 9

For six layers from the 2^{nd} internal electrode layer **13** to the 7^{th} internal electrode layer **13**, other than the exposure of the protrusion parts **13**a_1 to **13**a_3 of the internal electrode layers **13** connected to through the same connection electrode **14** without intentionally shifting the positions of the end parts of the protrusion parts **13***a* of the internal electrode layers **13** using the mask pattern with the shape as shown in FIG. **5**A, the thin film capacitors to be Example 9 were manufactured as similar to Example 8. In the manufacturing step, after two openings **21** to be the connection electrodes **14** were formed, the two openings **21** were observed toward the under electrode **11**, respectively, and it was confirmed that at least a portion of all the protrusion parts **13**a_1, **13**a_2 and **13**a_3 of the internal electrode layer **13** to be connected to the connection electrode **14** of the openings **21** was visible, respectively.

In addition, the capacitance of the thin film capacitors was measured as similar to Example 1, and its mean value and standard deviation were calculated. As a result, the mean capacitance (nF) was 40.09 nF and the standard deviation of the capacitance was 8.01 nF, and it was confirmed that the electric connection between the internal electrode layers **13** and the connection electrodes **14** became stable.

What is claimed is:

1. A thin film capacitor, comprising:

an under electrode;

a plurality of dielectric body layers and a plurality of internal electrode layers that are alternately laminated on the under electrode, the internal electrode layers respectively including protrusion parts that each protrude from the dielectric body layers viewed in the lamination direction; and

connection electrodes positioned perpendicularly to the plurality of internal electrode layers and/or the under electrode layer, to which at least a portion of each of the protrusion parts contacts the connection electrodes, wherein

assuming that insert amounts of the protrusion parts of the internal electrode layers that are connected to the same connection electrode are regarded as L, an insert amount Ln of a protrusion part of nth (n≥2) internal electrode layer from the under electrode side is smaller than another insert amount Ln−1 of another protrusion part of (n−1)th internal electrode layer.

2. The thin film capacitor according to claim **1**, wherein the insert amounts Ln and Ln−1 of the protrusion parts of the internal electrode layers satisfy

$$Ln-1-Ln>2\ \mu m.$$

3. The thin film capacitor according to claim **1**, wherein the connection electrodes include at least a first connection electrode and a second connection electrode, and assuming that an average of an insert amount difference of the protrusion amount Ln and the insert amount Ln−1 of the protrusion parts of the internal electrode layers connected through the first connection electrode is regarded as t**1**, and another average of the insert amount difference of the insert amount Ln and the insert amount Ln−1 of the protrusion parts of the internal electrode layers connected through the second connection electrode is regarded as t**2**, t**1** and t**2** are different.

4. The thin film capacitor according to claim **2**, wherein

the connection electrodes include at least a first connection electrode and a second connection electrode, and

assuming that an average of an insert amount difference of the insert amount Ln and the insert amount Ln−1 of the protrusion parts of the internal electrode layers connected through the first connection electrode is regarded as t**1**, and that another average of the insert amount difference of the insert amount Ln and the insert amount Ln−1 of the protrusion parts of the internal electrode layers connected through the second connection electrode is regarded as t**2**, t**1** and t**2** are different.

5. The thin film capacitor according to claim **3**, wherein

the first connection electrode is electrically connected to the under electrode; and

the averages t**1** and t**2** of the insert amount differences are in a relationship of t**1**<t**2**.

6. The thin film capacitor according to claim **4**, wherein

the first connection electrode is electrically connected to the under electrode; and

the averages t**1** and t**2** of the insert amount differences are in a relationship of t**1**<t**2**.

7. A thin film capacitor, comprising:

an under electrode;

a plurality of dielectric body layers and a plurality of internal electrode layers that are alternately laminated on the under electrode, the internal electrode layers respectively including protrusion parts that protrude from the dielectric body layers viewed in the lamination direction; and

connection electrodes positioned perpendicularly to the plurality of internal electrode layers and/or the under electrode layer to which at least a portion of each of the protrusion parts contacts the connection electrodes, wherein

among the protrusion parts of the internal electrode layers that are connected to the same connection electrode, when viewed from the lamination direction toward the under electrode, at least a portion of the protrusion part of (n−1)th internal electrode layer (n≥2) is exposed from the protrusion part of nth internal electrode layer.

8. The thin film capacitor in claim **1**, wherein an edge of each of the protrusion parts are curved.

9. The thin film capacitor in claim **7**, wherein an edge of each of the protrusion parts are curved.

10. The thin film capacitor in claim **1**, wherein the under electrode is longer than each of the plurality of internal electrodes in the horizontal direction.

11. The thin film capacitor in claim **7**, wherein the under electrode is longer than each of the plurality of internal electrodes in the horizontal direction.

12. A thin film capacitor, comprising:

an under electrode;

a plurality of dielectric body layers and a plurality of internal electrode layers alternately laminated onto the under electrode, the internal electrode layers each include protrusion parts that protrude from the dielectric body layers into the connection electrodes; and

connection electrodes positioned perpendicularly to the plurality of internal electrode layers and/or the under electrode layer, to which at least a portion of each of the protrusion parts contacts the connection electrodes, wherein

each of the protrusion parts has a different surface area.

13. The thin film capacitor in claim **12**, wherein the protrusion parts are arranged in descending order based on increasing surface area with a protrusion part having a greatest surface area being closest to the under electrode.

14. The thin film capacitor in claim **12**, wherein each protrusion part has a length that corresponds to a distance of the protrusion part from the under electrode, so that the protrusion part located farthest from the under electrode has a shortest length, and a protrusion part located closest to the under electrode has a longest length.

15. The thin film capacitor in claim **12**, wherein the surface area of each of the protrusion parts decreases as each protrusion part is positioned further away from the under electrode.

16. The thin film capacitor in claim **12**, wherein

a difference between respective lengths of adjacent protrusion parts exposed to the connection electrodes is at least 2 μm.

17. The thin film capacitor in claim **12**, wherein the under electrode is longer in the horizontal direction than each of the plurality of internal electrodes.

18. The thin film capacitor in claim **12**, wherein an edge of each of the protrusion parts are curved.

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